CLAIMS

1. A probing device for insertion into a duct having a physical structureto determine local parameters associated with the physical structure of the duct at a selected region of the duct, and in particular variations in the physical structure along a predetermined length of interest, the probing device comprising:

at least one of a plurality of waveguides incorporated in an elongated assembly designed to be inserted into the duct;

at least one of a plurality of transmitters, spaced and distributed along a predetermined length of said at least one of a plurality of waveguides incorporated in the elongated assembly, each capable of independently transmitting an acoustic signal of predetermined characteristics;

a plurality of receivers, spaced and distributed along a predetermined length of said at least one of a plurality of waveguides incorporated in the elongated assembly, each capable of receiving echoes of the acoustic signal, reflected off the structure of the duct;

whereby when each of said at least one of a plurality of transmitters generates an acoustic signal, echoes of the signal are received by the plurality of receivers and received data associated with the echoes is processed by a processing unit to determine parameters of the physical structure at the region.

2. The device as claimed in Claim 1, wherein at least some of said at least one of a plurality of transmitters and said plurality of receivers are combined in the form of receiving and transmitting transducers.

3. The device as claimed in Claim 2, wherein at least some of the transducers are piezo-electric transducers.

4. The device as claimed in Claim 1, wherein each of said at least one of a plurality of transmitters, comprises an absorbing region within an optical fiber, the absorbing region made from material, which converts optical signals to acoustic signals.

5. The device as claimed in Claim 4, wherein each of said at least one of a plurality of transmitters, comprises at least one of a plurality of absorbing regions within an optical fiber, the absorbing regions made from material, which converts optical signals to acoustic signals.

6. The device as claimed in Claim 5, wherein the absorbing regions are made of material that absorbs at different optical spectra, such that at least one of the absorbing regions are activated to generate acoustic signals at a certain optical spectrum, and other absorbing regions are activated to generate acoustic signals at one or more different optical spectra.

7. The device as claimed in Claim 5, wherein the absorbing regions are made of material selected from the group containing: Copper-doped material with absorption spectrum at about 450nm or shorter wavelengths, Alexandrite-doped material with absorption at about 850nm or longer wavelengths, and Yitterbium-doped material with absorption in the range 1,000-1300nm.

8. The device as claimed in Claim 4, wherein each of said plurality of receivers comprises at least one of a plurality of optical fibers through which light can traverse and be modulated by the echoes.

9. The device as claimed in Claim 8, wherein each one of said fibers, serving as a receiver, includes a reflecting element that effectively limits the extents of the fiber.

10. The device as claimed in Claim 9, wherein the reflecting element comprises a Bragg grating optical element.

11. The device as claimed in Claim 8, wherein at least some of said fibers serving as receivers are staggered along the length of interest to sensitize them to different regions along the length of interest.

12. The device as claimed in Claim 11, wherein signals are processed by subtracting signals of two detecting fibers, such that the resulting signal corresponds to their region where the two fibers do not overlap.

13. The device as claimed in Claim 8, wherein said fibers, serving as receivers, each include two reflecting elements and two types of light propagating in the fiber effectively forming two detection channels; the distal reflecting element serves to effectively limit the extent of the fiber for one of the detecting channels, and the proximal reflecting element serves to effectively limit the extent of the fiber for the other detecting channel; the differential signal between these two channels effects a sensitive region local to the separation of the two reflecting elements.

14. The device as claimed in Claim 13, wherein at least some of said sensitive local regions are staggered along the length of interest to sensitize them to different regions along the length of interest.

15. The device as claimed in Claim 13, wherein received signals are processed to account for different phases in each receiver in conjunction with a knowledge of physical separation between the receivers so as to effect a circumferential resolution in the device.

16. The device as claimed in Claim 13, wherein at least one of the two reflecting elements comprises a Bragg grating optical element, and the two channels are differentiated by wavelength.

17. The device as claimed in Claim 13, wherein at least one of the two reflecting elements comprises a polarization-dependent reflector, and the two channels are differentiated by polarization.

18. The device as claimed in Claim 13, wherein at least one of the two reflecting elements comprises a spatially selective element, reflecting one or more guided modes, and the two channels are differentiated by guided modes.

19. The device as claimed in Claim 4, wherein each of said plurality of receivers comprises at least one of a plurality of optical fibers through which light can traverse and be modulated by the echoes and which incorporates several wavelength-dependent reflectors, such that each effectively limits extent of a certain optical wavelength traveling in the fiber; the position of at least some of these reflecting elements is distributed along the length of the interest, sensitizing each wavelength to a different positions along the length of interest.

20. The device as claimed in Claim 19, wherein the received signals are processed to account for the different phases in each receiver in conjunction with a knowledge of physical separation between the receivers so as to effect a circumferential resolution in the device.

21. The device as claimed in Claim 1, wherein each of said at least one of a plurality of transmitters, comprises at least one absorbing region within a multicore optical fiber, the absorbing region made from material, which converts optical signals to acoustic signals, and wherein at least one of the cores serve as at least one receiver.

22. The device as claimed in Claim 21, wherein some of the cores serving to generate the acoustic signals have larger lateral cross section than those serving for detection.

23. The device as claimed in Claim 21, wherein the cores in the said multicore optical fiber, serving as receivers, include a reflecting element that effectively limits the extent of each of the receiver cores and sensitizes each on to a different positions along the length of interest.

24. The device as claimed in Claim 23, wherein the reflecting element comprises a Bragg grating optical element.

25. The device as claimed in Claim 21, wherein said cores, serving as receivers, include two reflecting elements and two types of light propagating in each core effectively forming two detection channels; the distal reflecting element serves to effectively limit the extents of the core for one of the detecting channel, and the proximal reflecting element serves to effectively limit the extent of the core for the other channel; the differential signal between these two channels effects a sensitive region local to the separation of the two reflecting elements.

26. The device as claimed in Claim 25, wherein at least one of the two reflecting elements comprises a Bragg grating optical element, and the two channels are differentiated by wavelength.

27. The device as claimed in Claim 25, wherein at least one of the two reflecting elements comprises a polarization-dependent reflector, and the two channels are differentiated by polarization.

28. The device as claimed in Claim 25, wherein at least one of the two reflecting elements comprises a spatially selective element, selectively reflecting one or more guided modes, but not reflecting other such modes, and the two channels are differentiated by different guided modes.

29. The device as claimed in Claim 1, wherein said predetermined length of the elongated structure extends to approximately 30 mm.

30. A probing device for insertion into a duct having a physical structure to determine local parameters associated with the physical structure of the duct at a

selected region of the duct, and in particular variations in the physical structure along a predetermined length of interest, the probing device comprising:

an elongated assembly designed to be inserted into the duct;

a plurality of transmitters, spaced and distributed along a predetermined length of said elongated assembly, each capable of independently transmitting an acoustic signal of predetermined characteristics;

at least one of a plurality of receivers, spaced and distributed along a predetermined length of said elongated assembly, each capable of receiving echoes of the acoustic signal, reflected off the structure of the duct;

whereby when each of said plurality of transmitters generates an acoustic signal, echoes of the signal are received by the at least one of a plurality of receivers and received data associated with the echoes is processed by a processing unit to determine parameters of the physical structure at the region.

31. The device as claimed in Claim 30, wherein said plurality of transmitters and said at least one of a plurality of receivers are combined in the form of receiving and transmitting transducers.

32. The device as claimed in Claim 31, wherein at least some of the transducers are piezo-electric transducers.

33. The device as claimed in Claim 30, wherein each of said plurality of transmitters, comprises an absorbing region within an optical fiber, the absorbing region made from material, which converts optical signals to acoustic signals.

34. The device as claimed in Claim 33, wherein each of said plurality of transmitters, comprises at least one of a plurality of absorbing regions within an optical fiber, the absorbing regions made from material, which converts optical signals to acoustic signals.

35. The device as claimed in Claim 34, wherein the absorbing regions are made of material that absorbs at different optical spectra, such that at least one of the absorbing regions are activated to generate acoustic signals at a certain optical spectrum, and other absorbing regions are activated to generate acoustic signals at one or more different optical spectra.

36. The device as claimed in Claim 34, wherein the absorbing regions are made of material selected from the group containing: Copper-doped material with absorption spectrum at about 450nm or shorter wavelengths, Alexandrite-doped material with absorption at about 850nm or longer wavelengths, and Yitterbium-doped material with absorption in the range 1,000-1300nm.

37. The device as claimed in Claim 33, wherein each of said at least one of a plurality of receivers comprises at least one of a plurality of optical fibers through which light can traverse and be modulated by the echoes.

38. The device as claimed in Claim 37, wherein said fibers, serving as receivers, each include two reflecting elements and two types of light propagating in the fiber effectively forming two detection channels; the distal reflecting element serves to effectively limit the extent of the fiber for one of the detecting channels, and the proximal reflecting element serves to effectively limit the extent of the fiber for the other detecting channel; the differential signal between these two channels effects a sensitive region local to the separation of the two reflecting elements.

39. The device as claimed in Claim 38, wherein each of said fibers serving as receivers are staggered along the length of interset to sensitize them to different regions along the device.

40. The device as claimed in Claim 38, wherein the received signals are processed to account for the different phases in each receiver in conjunction with a knowledge of their physical separation so as to effect a circumferential resolution in the device.

41. The device as claimed in Claim 38, wherein at least one of the two reflecting elements comprises a Bragg grating optical element, and the two channels are differentiated by wavelength.

42. The device as claimed in Claim 38, wherein at least one of the two reflecting elements comprises a polarization-dependent reflector, and the two channels are differentiated by polarization.

43. The device as claimed in Claim 38, wherein at least one of the two reflecting elements comprises a spatially selective element, selectively reflecting one or more guided modes, and the two channels are differentiated by guided modes.

44. The device as claimed in Claim 37, wherein each one of said fibers, serving as a receiver, includes a reflecting element that effectively limits the extents of the fiber.

45. The device as claimed in Claim 44, wherein the reflecting element comprises a Bragg grating optical element.

46. The device as claimed in Claim 44, wherein each of said fibers serving as receivers are staggered in their length to sensitize them to different regions along the length of interest .

47. The device as claimed in Claim 46, wherein signals are processed by subtracting signals of two adjacent detecting fibers, such that the resulting signal corresponds to their region where the two fibers do not overlap.

48. The device as claimed in Claim 33, wherein each of said plurality of receivers comprises an optical fiber through which light can traverse and be modulated by the echoes and which incorporates several wavelength-dependent reflectors, such that each effectively limits extent of a certain optical wavelength traveling in the fiber; the position of these reflecting elements is distributed along

the predetermined length of the device, sensitizing each wavelength to a different positions along the assembly.

49. The device as claimed in Claim 48, wherein the received signals are processed to account for the different phases in each receiver in conjunction with a knowledge of their physical separation so as to effect a circumferential resolution in the device.

50. The device as claimed in Claim 30, wherein each of said at least one of a plurality of transmitters, comprises at least one absorbing region within a multicore optical fiber, the absorbing region made from material, which converts optical signals to acoustic signals, and wherein several of the cores serve as one or more receivers.

51. The device as claimed in Claim 50, wherein some of the cores serving to generate the acoustic signals have larger lateral cross section than those serving for detection.

52. The device as claimed in Claim 50, wherein the cores in the said multicore optical fiber, serving as receivers, include a reflecting element that effectively limits the extent of each of the receiver cores and sensitizes each on to a different positions along the assembly.

53. The device as claimed in Claim 52, wherein the reflecting element comprises a Bragg grating optical element.

54. The device as claimed in Claim 50, wherein said fiber, serving as receiver, includes two reflecting elements and two types of light propagating in the fiber effectively forming two detection channels; the distal reflecting element serves to effectively limit the extents of the fiber for one of the detecting channel, and the proximal reflecting element serves to effectively limit the extent of the fiber for the other channel; the differential signal between these two channels effects a sensitive region local to the separation of the two reflecting elements.

55. The device as claimed in Claim 54, wherein at least one of the two reflecting elements comprises a Bragg grating optical element, and the two channels are differentiated by wavelength

56. The device as claimed in Claim 54, wherein at least one of the two reflecting elements comprises a polarization-dependent reflector, and the two channels are differentiated by polarization.

57. The device as claimed in Claim 54, wherein at least one of the two reflecting elements comprises a spatially selective element, reflecting one or more guided modes, and the two channels are differentiated by guided modes.

58. The device as claimed in Claim 30, wherein said predetermined length of the elongated structure extends to approximately 30 mm.

59. A system for determining local parameters associated with a physical structure of a duct at a selected region of the duct, and in particular their variation of a predetermined length of interest, the system comprising:

at least one of a plurality of waveguiding structures incorporated with an elongated assembly designed to be inserted into the duct;

a plurality of transmitters, spaced and distributed along a predetermined length of said at least one of the plurality of waveguides incorporated with the elongated assembly, each capable of transmitting an acoustic signal of predetermined characteristics;

at least one of a plurality of receivers, spaced and distributed along a predetermined length of said at least one of the plurality of waveguides incorporated with the elongated assembly, each capable of receiving echoes of the acoustic signal, reflected off the structure of the duct;

a processing unit for processing the received echoes;

a controller for actuating and controlling the operation of the generator and the processing unit,

whereby when each of said at least one of a plurality of transmitters generates an acoustic signal, echoes of the signal are received by at least one of the plurality of receivers and received data associated with the echoes is processed by a processing unit to determine parameters of the physical structure at the region.

60. A method for determining local parameters associated with a physical structure of a duct at a selected region of the duct, and in particular variations in the physical structure along a predetermined length of interest, the method comprising:

providing a system comprising:

a probing device comprising at least one of a plurality of waveguiding structures incorporated within an elongated assembly designed to be inserted into the duct; at least one of a plurality of transmitters, spaced and distributed along a predetermined length of said at least one of the plurality of waveguiding structures incorporated with the elongated assembly, each capable of transmitting an acoustic signal of predetermined characteristics; and at least one of a plurality of receivers, spaced and distributed along a predetermined length of said at least one of the plurality of waveguides incorporated with the elongated structure, each capable of receiving echoes of the acoustic signal, reflected off the structure of the duct;

a processing unit for processing the received echoes;

a controller for actuating and controlling the operation of the generator and the processing unit,

inserting the probing device within the duct at a desired target;

generating an acoustic signal by each of said at least one of a plurality of transmitters;

receiving echoes of the acoustic signal;

processing data associated with the echoes by the processing unit to determine parameters associated with a physical structure of a duct at the desired region.